

Far far away: driving HMI requirements towards the comfortable range in Electric Vehicles

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Abstract— This papers discuss the most wide-known problems in the market penetration of the Electric Vehicles, with a focus on the so-called “range-anxiety”. The it presents the results of a survey with domain experts concerning the HMI features of electric vehicles. The survey was realized within the RESOLVE project. The RESOLVE project aims at enabling the development of a range of cost-effective, energy efficient and comfortable Electric Vehicle for L-Category (ELVs).

Keywords— Driving Experience, Driving Style, Electric Vehicle, Ergonomics, HMI, range anxiety, survey

component; formatting; style; styling; insert (key words)

I. INTRODUCTION

European cities are increasingly congested due to the increased demand and usage of motor vehicles of a growing urban population [4]. As these vehicles become more numerous, emissions increase, parking gets scarcer, and noise levels pollute the urban air.

These factors affect the quality of life and health of city-dwellers. One of the most feasible alternatives to traditional Internal Combustion Engine (ICE) is represented by Electric Vehicles for L-category¹ (ELVs), but the rate of adoption of these vehicles is not high enough because electric vehicles are unable to compete with traditional ICE vehicles. The reasons are many: the technology involved is not affordable enough, the models currently on the market do not provide a similar or superior experience to the driver (in terms of comfort, handling, stability, etc.).

Thus, limited driving range, long charging time, and high purchase price were identified as the main concerns for consumers [8].

¹ Concerning the EU law, vehicles that belong to L Category are Mopeds and motorbikes, as well as all-terrain vehicles (quads) and other small vehicles with 3 or 4 wheels. Within category L, motorbikes are further subdivided into 2 groups (with and without sidecars). There is also a subdivision for mopeds with 3 wheels, which have smaller engines and lower top speeds than motor tricycles [5].

Nevertheless some recent researches state that people were willing to pay a significant amount to reduce emission and save on gas [8].

Working towards that vision, RESOLVE project [11] aims at enabling the development of a range of cost-effective, energy efficient and comfortable ELVs that will entice ICE car drivers to switch from cars to ELVs for their daily urban commutes.

II. THE RESOLVE PROJECT

The Resolve - Range of Electric Solutions for L-category Vehicles project is a three years research project co-funded by the European Commission within the H2020 program, started the 1st May 2015.

The Resolve consortium is made of a well-balanced and qualified group of 14 partners and it is optimally positioned to drive such technological advancements and bring them to the market: PIAGGIO and KTM (each developing one of the demonstrator vehicles) are the two largest LV producers in the EU, while the complete ELV value chain is represented in the consortium, complemented by top component suppliers, research institutes, engineering companies and universities.

III. USER EV-ORIENTATION

From the survey led by [8] it is possible to identify some user's features about his/her age, education, lifestyle, believes, and behavior that male him/her more EV-oriented.

The following variables increase a respondent's EV-orientation with statistical significance:

1. Being younger or middleage
2. Having a BA or higher degree
3. Expecting higher gasoline prices in the next 5years
4. Having made a shopping or lifestyle change to help the environment in the last 5 years
5. Likely to buy a hybrid gasoline vehicle on their next purchase

6. Having a place they could install an EV electrical outlet at home
7. Likely to buy a small or medium-sized passenger car on next purchase
8. Having a tendency to buy new products that come on to the market
9. Taking at least one drive per month longer than 100 miles

As elicited by the authors of the study, the first eight features were expected. The ninth, taking one or more frequent long drives a month, is counterintuitive instead.

It belongs to common sense to expect that people making more long drives would be less inclined to buy an EV due to limited driving range and slow refueling. This result may come from an interest in saving fuel indeed. People traveling longer distances pay more for fuel, hence they can be interested in saving more money using EVs.

IV. IMPROVING DRIVER EXPERIENCE WITH ELVS

To encourage car drivers to use ELVs for part of their commuting needs, ELVs need to move closer to what car drivers expect from their mobility solutions by enhancing the driver's user experience.

The RESOLVE project aims at making advancements to the handling and stability of ELVs together with improving the user interface that will assuage range anxiety and other driver concerns, such as safety and comfort. In the following a focus on the range anxiety.

A. The range anxiety

"How far does it go?" Frequently this is one of the first questions that come into people's minds when hearing of a new electric vehicle. For the common user that is not experienced in EVs, the perception of limited mobility resources is a barrier to purchase intentions [2] [6].

Although EV field trials have a long-standing tradition [1] [10], there is very little published research about the nature of how real users experience EV range and how they subsequently deal with it [6].

The field study presented in [6] states that the range was experienced as a major resource used for interacting with an electric mobility system. This means that users evaluated range centrally in terms of its level of sufficiency. The most part of the users involved in such a research elaborated a lot of thought about the trips they could and could not perform with a given range. On the Human Factors point of view, this thoughts refer a more general concept of mobility needs that one could or could not fulfill with the range resources provided by the EV.

The range experience can be analyzed also according to the emotional dimension. From the same study researchers recorded that users never mentioned range as a feature that made them feel especially positive about the EV. However, for

a few users dissatisfied with range, negative emotional states resulted, and the most prominent of these was annoyance.

The authors reason also about the absence of positive emotions that can be interpreted as a Zeitgeist effect because today, the range of an ICE vehicle is a primary anchor from which users evaluate the range. This only leaves EV users the option of evaluating reduced range as either neutral or negative.

At least range can be considered as a resource: to deal with this resource, users often settled on certain heuristics to manage the range resources, such as evaluating range in terms of sets of typical trips (e.g., twice to work and back and once shopping) that could be comfortably done with the EV.

Another interesting issue discussed in [6] is the categorization of the EV range into four levels that track the transition to the objective range data to the subjective perception of the range itself.

- The **cycle range** is measured according to a standardized driving schedule
- The **competent range** is the range that each individual user could obtain based on his/her eco-driving competence and system knowledge. In fact, EVs energy consumption is influenced in particular by use characteristics [12]. This implies a gap between the competent range of individual users and the cycle range of the EV.
- The **performant range** is usually obtained by each user based on his/her eco-driving-related motivational strengths and habits. Driving behavior is influenced by various motives [7].
- The **comfortable range** refers to the range that users really utilize. This can be defined as the highest trip distance between two charging opportunities or the lowest remaining range status, which a user experiences as comfortable. This definition attempts to merge absolute value range buffer decision variables [9] with the broadly defined concept of range anxiety in terms of a "fear of becoming stranded" [13].

Comfortable range may reflect the result of an adaptation process that involves anchors and heuristics from internal combustion engine (ICE) powered mobility systems, and ultimately result in an equation involving individually perceived levels of performant and competent range [6].

V. SURVEY WITH EXPERTS ON HMI REQUIREMENTS

Notably, the concept of electricity in the car evokes questions not only about safety, but also about energy consumption: HMI is decisive in the evaluation of complex, unfamiliar technological systems such as EVs, considering also the range anxiety problem discussed before.

Designing the HMI for EVs, the questions that designers try to answer to are: "what relevant parameters should be displayed in an EV? How should the driver be informed about these important parameters" [3].

In order to identify the main HMI requirements for EVs in general, a survey for domain experts was set up. Experts belongs to the ergonomics, human factors and engineering domains.

For the HMI requirements domain experts was preferred to final users since final users may not have an in-depth knowledge of the whole range of in-vehicle HMI functions for the automotive domain generally, and for the EVs domain specifically. Since the survey aim is to identify the core functions set the HMI shall have, the experts' feedbacks are more effective to collect data for the design of RESOLVE HMI concepts.

That said, the survey encompassed three different sections:

- Sample profile
- Functions for EVs
- Interaction modalities

Twelve questions for HMI functions and interaction modalities were included in the questionnaire.

A. Sample profile

The sample is composed of 74 experts mainly 25-34 years aged (52.7%), male (82,4%), and with a master degree (68,5%).

B. HMI functions

Seven questions were provided to experts to evaluate which kind of HMI functions should be available on an Electric Vehicle.

TABLE I. ANSWERS TO THE SECTION ABOUT FUNCTIONS FOR EVs

	Disagree	Agree	No opinion
Available range estimation to reduce "range anxiety"	0%	99%	1%
Energy used (spent/recovered)	10%	89%	1%
Suggestions on how to improve driving style in terms of energy consumption (e.g. improving regenerative braking)	12%	86%	1%
Suggestions on how to improve driving style in terms of safe riding	49%	46%	6%
Availability of charging infrastructures in the surroundings	0%	96%	4%
In-deep data about vehicle and driving status (e.g. consumption based on routing, diagnostics)	21%	78%	1%
In-deep data about route (e.g. navigation, traffic)	10%	90%	0%
Other (please specify in next row)	8%	41%	51%

There are three aspects that come out impressively.

Almost all interviewed experts strongly agree (99%) on the importance of the range indicator, in order to handle the user range anxiety.

There is a split in expert opinions about the possibility of providing the user of suggestions aimed at improving the driving style in terms of safe riding, with a slight propensity

for the unfavorable answers. More agreement (86%) was collected instead about the possibility of providing the user of suggestions aimed at improving the driving style in terms of energy consumption. This last aspect is consistent with the strong agreement on the need to reduce the "range anxiety".

Finally the whole sample agrees on the importance of providing the user with the information on the availability of charging infrastructures in the surroundings.

Furthermore some comments were provided, suggesting additional types of functions to be included in the HMI.

- Instant consumption
- Instructions for recharging
- Offline analysis of actual performance compared to prediction, with advices on how to get closer to the expected.
- Status of battery (e.g. wear-level), battery health status (e.g. how many more loading circles will the battery last)
- Personal settings to give the user the possibility to custom the warnings (i.e. visual vs acoustic or haptic)
- Weather information
- Front wind expected (that impacts on range)
- Alarm over Smartphone when 100% battery limit is achieved during charging on open charge points
- Remaining charging time (during charging)
- Time for recharge, battery status (maintenance intervals and function) but this information does not need to be present all time
- Infos about Co2 or other emission saved, to rise green sensibility

C. HMI interaction modalities

Five questions were provided to experts to evaluate which kind of HMI interaction modality is most suitable for an Electric Vehicle.

TABLE II. ANSWERS TO THE SECTION ABOUT INTERACTION MODALITIES

	Disagree	Agree	No opinion
All information to be provided through On-board system	18%	82%	0%
Additional data to be provided through mobile device (e.g. app for energy consumption trends)	28%	72%	0%
Driving data to be communicated using visual and auditory channels	25%	72%	3%
Critical information to be highlighted through haptic/tactile channels (e.g. for safety)	8%	84%	8%
Interface should be configurable to cope with different users needs (e.g. bigger size fonts for elderly users)	6%	94%	0%

Other (please specify in next row)	7%	21%	72%
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Considering the answers to all questions at a glance, it comes into evidence that also EV vehicles shall follow the current technological standard level in HMI interaction of ICE vehicles. Hence experts expects that EV vehicles will offer the drivers the same comfort and user experience of traditional vehicles, giving for example the possibility to have extra in-vehicle functions through Smartphone connection or taking advantage from the warning capabilities of haptic interaction.

A further comment on the HMI interaction modalities it to include in the design of the HMI adaptation strategies, in order to make the HMI context sensitive, following the user configuration requests.

D. Discussion

This survey paved the way in understanding the user needs regarding the HMI. Thanks to the evidences of the HMI survey, it is possible to classify the HMI functions into 6 categories:

1. Range
2. Driving style
3. Recharge
4. Route
5. Vehicle info
6. Personal settings

Range category will include:

- Consumptions
- Range
- Energy used (spent/recovered)

Driving style category will include:

- Suggestions on how to improve driving style in terms of energy consumption (e.g. improving regenerative braking)
- Eco-info

Recharge category will include:

- Availability of charging infrastructures in the surroundings
- Instructions for recharging
- Status of battery, battery health status
- Remaining charging time

Route category will include:

- Navigation
- Traffic
- Weather information

Vehicle info category will include:

- Diagnostics
- Suggestions on how to improve driving style in terms of safe riding
- Consumption based on routing
- Data download for offline analysis of actual performance compared to prediction, with advices on how to get closer to the expected.

Personal settings category will include:

- Functions customization
- Vehicle customization
- Info displaying customization

What comes into evidence is the importance of delivering to the users the information about the factors that increase the efficiency of EV range use, in order to cope with the accompanying stressfulness of such range utilizations. This is the basis for discovering feasible approaches to enhancing usable range for electric mobility users. Based on the current findings, instead of simply maximizing range, it may be more desirable to offer reliable and affordable range setups that meet perceived mobility needs, or more specifically, that result in a reasonably high comfortable range [3].

VI. CONCLUSIONS

The HMI will provide drivers with advice on their driving style on the optimal usage of ELVs. It will give feedback on driver behaviour, such as how drivers have to behave to recuperate the most energy for regenerative braking and how to optimise the active safety systems.

HMI has to provide suitable means to cope with range anxiety, adopting fallback options in terms of recharging opportunities, increasing user awareness of his/her driving style, incorporating information related to confidence in displayed remaining range estimations or adding navigational references [6].

Future works within RESOLVE project will encompass the exploration of different HMI architectures in order to maximise the ease of use, intuitiveness, and ad-hoc controls that will enable the driver to have better, safer and more effective interactions with the ELV.

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